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Controversial science-based technology public attitude formation and regulation in comparative perspective: The state construction of policy alternatives in Asia

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ABSTRACT

Past studies of the success of regulation and other forms of state and private sector activity in areas of new technologies have argued these are dependent on a number of factors, one of which is the reaction of public opinion to the innovation concerned. Most existing theories of public acceptance of controversial science-based products are based largely on European and North American case studies and are divided between those which focus on public and consumer knowledge of the science involved – the 'deficit model' - and those which stress either the need for trust in regulatory and private sector actors involved in new product development and regulation, or the significance of individual cultural norms on attitude formation. This paper examines two cases of the introduction of controversial science in Asia - wastewater recycling in Singapore and nanotechnology regulation in China in order to assess the influence of these factors in each case. Based on this comparative research, it is argued that models of public acceptance of controversial science-based products must also take into account the state's ability to define the range of public debate as a key overall parameter of public attitude formation.

1. Introduction

Regulatory policy-making in the field of new technologies affecting consumer products involves the design and adoption of a set of policies related to product safety which are expected to receive a high level of public support. Public attitudes towards the technology in question thus play an important role in the determination of the content and orientation of technological regulatory regimes.

The existing literature on the subject of public attitude formation towards controversial technologies, however, is derived largely from European and North American experiences. Studies of public opinion towards science and technology based on these case studies divides into three main competing approaches, all of which focus on individual behavioural characteristics found to be associated with public attitudes towards the development and deployment of controversial technologies. These are, respectively, on individual levels of knowledge and attentiveness towards science, on individual levels of trust in institutional actors and regulatory bodies, and on citizens' values and ethical considerations related to the deployment and possible side-effects of the technology in question [76].

However it is important to know if this focus on individual characteristics is exhaustive or unduly restrictive due to the choice of case study subjects utilized in most existing studies. The emphasis found in these models on societally-driven opinion formation, for example, may underplay the role of the state in framing scientific controversies, a subject which is of great significance in many countries outside of the North American, European and occasionally Australasian ones commonly examined in studies of the subject. This paper examines two case studies

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of public reception of controversial technologies in two countries in Asia—Singapore and China—which feature strong states. As these case studies show, models of public attitude formation should take the role of the state more seriously in developing models of general applicability on the subject of opinion and attitude formation towards controversial science-based technologies.

1.1. Existing models of regulatory regimes and attitude formation in areas of scientific and technological controversy

Haga and Willard [33] provide a framework helpful to understand and explore the sets of government activities undertaken in emerging areas of public policy based on leading edge scientific and technological breakthroughs. They argue that five regulatory dimensions to new technology regulation can be identified: research issues, legal issues, economic issues, education issues and acceptance and implementation issues. Specific issues with which regulatory regimes grapple include intellectual property rights, public information, commercialization of retail products, safety, health, consumer choice, trade, and research investment [70].

Different countries deal with these issues differently Paarlberg [48] and understanding why these variations exist is a key unanswered question in the literature on the subject of regulation and public attitude formation towards controversial science-based technologies. Of the five general dimensions Haga and Willard identified, four are fairly well developed in the literature on science and public policy. Much is known about the research, legal, economic and education issues involved in regulatory activity. The "acceptance and implementation" dimension, however, remains a subject of some controversy, and duelling explanatory models, in the literature [10].

The starting point for most studies of public opinion towards new technology products in the North American and European studies which make up by far the largest bulk of existing studies is individuals' knowledge and understanding of these new technologies. The so-called "Deficit Model" endorsed by many practioners, if not empirical studies [27,36,67], for example, holds that attitudes towards emerging technologies stem largely from individual ignorance about their actual benefits and irrational fears of potential risks. The chief assumption of this model is that the public would embrace industry and regulatory experts' support for these technologies if it were simply more knowledgeable about the actual benefits and risks of these technologies.[1] Public education is thus often prescribed as a necessary correlate of promotional policy-making although sensationalist media coverage and oppositional groups' campaigns are seen as undermining these efforts [37,50,52,56,68]. However the empirical basis for such claims is dubious[2] and the model often obscures the intent of public education measures: to provide a level of public support required in democratic states for enhanced levels of promotional government activity in the area concerned.

The same is true of a second literature on public support for new technologies which focuses on individuals' ethical concerns and core values [49,69]. Although this literature moves away from purely individual orientations towards more collective, cultural, sources of individual opinion formation, this second literature in its emphasis on cultural values, like the deficit theory which preceded it, is still very 'society-centric' and sees the proper role of the state as simply responding to accommodating pre-existing cultural predilections. Key drivers of individual attitudes in this literature include individual religious and moral inclinations, as well as quasi-spiritual orientations related to the natural order/protecting nature in areas such a biotechnology.[3]

This is somewhat different, but not entirely, from the third major stream of literature developed from case studies of western democratic societies, that focusing on the institutional context of scientific research, including individual levels of trust in regulatory actors and stakeholders as a key determinant of individual attitudes and actions [16,53,74]. Trust in institutional actors is seen as being important because in many societies they are a key source of "official" information on science and technology. As such, it is argued, scientists and state regulators can play a critical role in providing ostensibly neutral or objective information to the public [20], but when these institutional actors are not trusted, their claims are likely to fall on deaf ears, or be consciously rejected [19,38]. Individuals will

[1] As Weldon and Laycock (71) note, at the aggregate level, survey findings provide some evidence to support this interpretation. Study after study has shown that the public is "scientifically illiterate," lacking even a basic understanding of science, let alone knowledge of sophisticated new technologies (e.g., [45,46,68]). For example, a 1999 Eurobarometer survey that asked ten basic high school-level biology questions, including several about genes and biotechnology, found that the average respondent across 17 West European countries could only answer 5.2 of the questions correctly [77]. Surveys in other advanced industrial democracies, including the United States and Canada, have found comparable results [78].

[2] Empirical studies, particularly from the more general public understanding of science literature, however, have found a positive, but only very weak, correlation between levels of scientific knowledge and levels of support for new technological advances (see, for example, [11,27,47,67]). In fact, more recent studies suggest that this would not necessarily lead to greater support of new technologies as predicted by this model. The strongest test of the model probably comes from studying participants in deliberative public forums on specific technologies. Early research suggests these experiences may actually heighten participants' concerns about the risks and decrease support for the new technologies. For example, a recent study of a nanotechnology citizen forum in the United States found that before deliberation, 82 percent of participants thought the potential benefits of the technology outweighed the risks; that number dropped to 66 percent after the deliberation period [30,35].

[3] In a widely cited paper, for example, Sjoberg [64] showed that earlier studies' inattention to moral considerations as bases of technological risk perceptions left much of the variance of perceived risk unexplained. When 'unnatural and immoral risk' factors were incorporated into his analysis of the perceived risk of nuclear wastes in Sweden, his model's explanation of variance increased from 20 percent to 66 percent [64]. In a second 2005 study of public and expert attitudes towards 18 gene technologies, Sjoberg again showed that public concerns about interfering with nature, the moral value of technology, and trust in science offered stronger explanatory force than affective and risk assessment factors [65]. To Sjoberg, these concerns are rooted in ideological convictions, comparable to the worldviews and spiritual orientations anchoring attitudes towards technology in general.

then look to other sources of information, such as relatives or friends, social or political organizations, or other perceived experts, as a conscious basis for their judgments [12]. The empirical basis for this third strand in the literature is quite strong. As Weldon and Laycock [71] note, previous research confirms the importance of trust in institutional actors for support of new technologies [25,32,53,62]. As they discuss [51], Priest found that for explaining variations in individual support for biotechnology in the United States, trust in agricultural, biotechnology, and food retail corporations was more important than knowledge about genetic or genomic science while Barnett et al. [9] found that levels of trust in government rules and regulatory bodies in Great Britain are also much stronger predictors of support for gene therapy, human cloning, and genetic databases than attentiveness to genetics and education [14].[4]

All of these models, however, including the public trust one, do not systematically assess the role played by the state in framing debates and opinions concerning controversial technologies.[5] Rather states are seen largely to be at the mercy of "public opinion". While this may be the case in some European or North American countries, however, the state plays a much larger role in many countries than in western-European or Anglo-American liberal democracies and it remains an open question whether public opinion towards controversial science in such countries follows North American or European liberal–democratic patterns of individual attitude formation and behaviour. Although participation of the public and stakeholder groups in the technology-driven policy process is a subject that has received a great deal of attention in more recent years ([29,33,34,61]), the underlying micro-motives of individuals faced with choices about whether to buy or support the introduction of products based on new technologies remain uncertain [63].

In what follows below, the introduction and deployment of two controversial technologies—recycled water use and nanotechnologies—are studied in two countries in Asia with strong, active, states, Singapore and China, respectively. As the discussion will show, framing effects undertaken by state actors—in the one case related to the promotion of the view of a lack of alternatives towards the technology used and, in the other, the close association of the technology with national development plans and goals—are shown to be crucial determinants of public opinion and attitudes towards these technologies, which are perceived much more favourably in these two jurisdictions than they are in Europe, North America or Australasia.

[4] In fact, when controlling for trust factors, Weldon and Laycock [71] found that attentiveness and education have been negatively correlated with support for these modern technologies [9]. Looking more closely at feelings of trust towards competing regulatory and social group actors, they found Priest et al. [53] to have "argued compellingly that individuals often trust these two actors at markedly differing levels, and that the "trust gap" is the most decisive factor in explaining variation in individual attitudes towards biotechnologies".

[5] Although still society-centric in its focus on individuals as key shapers of public attitudes, unlike the deficit and cultural models, the institutional trust analysis does begin to hint at a much more significant role being played in opinion formation by state institutions.

2. Case studies of controversial science-based technology deployment in Asia

2.1. Singapore NEWater

Since independence in 1965, Singapore has been dependent on its neighbour Malaysia for much of its water, with two long-term water agreements ensuring water supply. Over the past four decades, the two countries have experienced periods of cordial as well as icy bilateral relations. In 1997, Singapore, precipitated by difficulties with Malaysia over establishment of the price of raw water, with the Malaysians threatening to increase prices by at least six times and with no set formula upon which to peg to future increases, publicly stated that it was looking at alternative sources of water [40].

Shortly thereafter, in 1998, Singapore began studying wastewater as a source of raw water. The water would go through a purification and treatment process using membrane and ultraviolet technologies and, three years later, the reused water would be ready for non-potable use–such as wafer fabrication applications in manufacturing processes, as well as for air-conditioning cooling towers in commercial buildings. In 2003, the reused water, named NEWater, was introduced into water reservoirs. The amount made up about 1% of total daily water consumption in 2009 and was increased progressively to about 2.5% of total daily water consumption by 2011 [40].

2.2. Early water reuse in Singapore

Singapore is one of the few countries in the world which has been able to overcome the "yuck" factor in implementing recycled water for drinking. The few studies that have documented this case point to the careful use of framing by the government [39] that included stress on the idea that Singapore had no alternative sources of water, despite the fact that options such as desalinization or importing water from neighbours at higher costs, existed.

Since the early 1960's, with increasing industrialization and a larger population, the government started to review its water sources and considered nonconventional options such as the reuse of sewage and desalination. By the 1960's, two large sewage treatment plants had been built and by 1971, some 36 industrial premises were using industrial water. But its use was limited because of poor quality. In early 1970, there was also a small experiment to use industrial water for toilet flushing. But homeowners were unhappy with the smell and the dirty water and foaming which resulted. Pipes and pumps also corroded more quickly then expected. Despite this, the government continued its efforts. In 1974, it commissioned an S$1.3 million Wastewater Reclamation Demonstration Plant to determine feasibility of reclaiming wastewater. The plant produced drinking water that fully met and in some instances exceeded WHO International Drinking Water Standards. However, at S$1.10 per m3 of water, the plant was not cost efficient and was decommissioned in late 1975. But it had proven that it was possible to reclaim water of good quality from treated wastewater, and moreover, that reclaiming water from wastewater was cheaper than desalination.

2.3. Drinking reused water: NEWater

Some two decades after the Wastewater Reclamation Demonstration Plant closing, the government returned to the idea of reusing wastewater. It sent a team to study water reclamation projects in California and West Virginia and on return, built its second Water Reclamation Demonstration Plant. The S$7 million plant was completed by May 2000. It used a dual membrane (microfiltration and reverse osmosis) and ultraviolet light disinfection process. This method followed the recommendations of the United States National Research Council in its report on the use of reclaimed water to supplement water supplies.

At the same time, the government also put together an Expert Panel comprising local and foreign experts in engineering, community health, analytics, and water quality. They provided independent advice to the Public Utilities Board (PUB) and the Ministry of the Environment on the newly renamed "NEWater" study. NEWater was also tested–more than 20,000 analyses and tests, evaluating 191 parameters, were carried out. At the end, the Expert Panel concluded NEWater was safe for potable use and recommended Singapore consider using it for indirect potable use by blending it with reservoir water. Rather than pumping it directly into the water supply, NEWater would first be pumped into reservoirs, and then submitted to conventional water treatment. This not only provides an additional safety margin and but was expected to garner greater public acceptance by transforming the reused water into a 'natural' product. The Expert Panel also recommended that the PUB put in place a rigorous monitoring and testing program as long as NEWater has indirect potable use, with water quality test results reviewed by local and international experts from academia and industry [41].

2.4. High science, low acceptance: buy in from the people

From the PUB's point of view, the main goal was to garner public confidence and acceptance. The introduction of a new source of water supply was unprecedented for the small island state of Singapore, which has relied on two traditional sources of water—from local catchments and imported water from the Malaysian mainland—since its independence 40 years ago. It was considered critical to ensure that the introduction of NEWater did not meet with any significant public opposition. The main aim was to attain the same level of trust that the population had in PUB water to NEWater.

The processes outlined above—dual membrane technology and ultraviolet light disinfection as well as process indirect potable use—were new to the general public, but generally well known in scientific circles. As a senior PUB official said: "The most difficult, yet critical of them all, was to get the public to overcome their psychological barrier towards drinking recycled water and convince them to embrace NEWater as a source of drinking water. To overcome this barrier, a deliberate attempt was made to shift the attention away from the source by focussing on the treatment process, which involves using advanced, state-of-the-art membrane technology." The PUB tackled the terminology by consciously renaming the terms that had a negative connotation with terms that would better reflect the process or value as a resource. They did not use internationally recognized terms such as 'wastewater' or 'sewage' because these had a negative connotation but rather settled on: a term which promised a 'new and improved" product "NEWater" [40].

The PUB official said: "We also wanted the public to understand that this water is technically not wastewater to be thrown away but water that can be used and reused over and over again, similar to how water recycles itself in nature. The plants were renamed from sewerage treatment plants to water reclamation plants as they were not merely treating the sewage, but part of the process that reclaims the used water for reuse." [40].

2.5. State-led re-framing of recycled water

The PUB briefed the media and subsequently brought reporters to places in the United States such as Orange County in California and Scottsdale in Arizona to demonstrate that water recycling is not a new phenomenon, and that it has actually been a way of life for people for many years. The PUB also explained the difference between unplanned indirect potable use which has been practised by cities in Europe for centuries—treated used water is channelled back into the rivers for use by the next city downstream and re-channelled back to the same river for use by yet the next city downstream of it, and this goes on and on—and planned indirect potable use, which Singapore is practising—where the PUB purifies the treated used water to high standards and mixes a percentage of it with raw reservoir water before treating it for the drinking water supply. The PUB also bottled NEWater in attractive packaging so that the public could sample for themselves how pure it is, and these were distributed at grassroots and national events. Top government officials became 'NEWater' ambassadors and champions when they were seen drinking NEWater publicly [40].

During the 2002 National Day, some 60,000 Singaporeans toasted NEWater, demonstrating the support and confidence they had in it. The PUB also set up the NEWater Visitor Centre to bolster the public education campaign which was opened by then Prime Minister Goh Chok Tong in 2003 [41].

However, despite the expert panel and adherence to international standards, the issue of public acceptance continued to dog attempts by governments to introduce reused water. In Singapore's case, however, the introduction of NEWater was greatly helped by the government generating a sense of crisis over the 1997 Malaysian government decision to revise the price of water piped to the city state. This was a major plank in a concerted and strong effort from the Singapore government to "market" NeWater to the public [40].

Overall, the government made all these arrangements in order to "blow down" the "yuck" factor and concentrate on issues of strategic survival and economic viability. This strategy of legitimation did this in three steps. First, it worked on companies first –introducing NEWater as a substitute for municipal supply in industry (eg in semiconductor wafer fabrication plants and in air-conditioning cooling towers). Second, it held a massive grassroots campaign to frame the issue in such a way that showed that the science was relatively uncontroversial, and in any case, there was no alternative. Third, it also introduced the water indirectly by pumping it into reservoirs [40].

In just five years NEWater has augmented Singapore's water supply by 302 000 m3/d or about 15% of water consumption. The four existing NEWater plants can now meet more than 15% of Singapore's water demand - well ahead of the 2010 target date. Construction of the fifth 227 000 m3/d NEWater factory at Changi and expansion of the existing plants has been advanced to meet growing demand. By 2011, the first in which the first of the two water agreements with Malaysia expires, the five NEWater plants will have a combined capacity to meet 30% of Singapore's water needs.

2.6. Conclusion

As Dolnicar and Hurlimann [22] concluded in their study of Australian water use attitudes, Singapore provides evidence that key factors involved in the acceptance of this controversial science product includes cost- when compared to more or less equally unpalatable alternatives–and the consequences of a perceived lack of palatable alternatives. However in the Singaporean case a key role was played by governments in transmitting this knowledge and framing the discussion in such a way as to portray the unpalatable alternative in as favourable a light as possible. In Singapore, the argument about a lack of alternatives proved particularly strong since the country is dependent on its neighbour for two thirds of its water supply and the issue could be framed as one of national survival. A comparison of Singapore's case with that of Queensland Australia, which also tried to implement water reuse in its drinking water supply, showed that the discourse in Singapore's case was markedly different in its tone [23]. Media reports showed a higher degree of neutrality and focused on the practical implications, rather than the physiological aspects of water reuse [39].

3. Nanotechnology in China

The ability to arrange atoms lies at the foundation of many technologies [26]. It is merely variation in the arrangement of atoms that differentiates sand from computer chips, cancer from healthy tissue, or gold from bauxite. Nanotechnology involves a series of technologies that begin to change the molecular structure of biological entities, proteins, DNA, and the building blocks that generate and control biological outcomes. These technologies are able to engineer molecular and atomic variation in the composition of compounds to produce new materials with new properties and characteristics. DNA engineering, for example, can build precise, million-atom frameworks where "engineered proteins can bind to precise locations on these frameworks," and where "proteins can bind other components" that are electrically or chemically active such that these proteins and the biological structures on which they are attached "serve as construction machinery" [26].

Nanotechnology is thus a diverse collection of academic specialisms centred around engineering and manipulating molecular and atomic structures and, in the process, creating biological and non-biological nanomaterials whose characteristics can be made to order. It deals with structures sized between 1 and 100 nm in dimension | 1 nm being equal to one billionth of a meter [42,55]. This holds vast prospects for technological innovations in areas such as electronics through the development of nanocircuitry, molecular level semiconductors, nanotubes, new materials development in ceramics, polymers, glass ceramics and composites, and in medicine with the development of nanoelectronic biosensors and nanoscale drug particles and delivery systems to improve the accuracy and efficiency of drug toxicity to harmful tissue and disease among many others.

Nanomaterials are currently present in over 1200 commonly consumed products ranging from cosmetics, clothing, personal care and hygiene items, sporting goods, sunscreen, and in household filtration systems and construction materials. The paper ring that holds a MacDonald's hamburger together is glued with a nano based resin; wounds are now often dressed with an "Acticoat" dressing or applied "Acnel" lotion for dry skin, each with nanomaterials incorporated into their production [54]. The US National Science Foundation estimates that $70 Billion worth of nano containing items are sold in the United States each year while the global market for manufactured goods containing nanotechnology is estimated to reach $2.6 trillion by 2014 [4,44]. The rate of development and incorporation of nanotechnologies into all facets of consumer, industrial, and medical applications is anticipated to double every two years [24].

While the United States has led global investment into research and development in nanotechnology, China is fast emerging as a global player. By 2005, China ranked second only to the US in nanotechnology investment, ranked second again in terms of the number of nano-related peer reviewed research publications–producing 15% of all global nano-related research papers -and had emerged as the global leader in carbon nanotube technology and manufacture, as well as a leader in the manufacture of nanocoatings, anti-corrosive nano paints used in ship construction and oil tanks, odor eating nano-coatings and plastics for refrigerators, nano filters for air conditioners, as well as a series of nanomaterials used in optics to filter glare and in the production of nano textiles and clothing to enhance antimicrobial properties [43,60].[6]

China's push to become a global leader in nanotechnology reflects a national strategy aimed at leapfrogging the developmental cycle. While development of the export sector has facilitated rapid economic growth primarily through specialization in low to medium value-adding manufacturing, sustained growth will be contingent on moving up the value chain. Leading Chinese policy makers, economic planners and influential economists all recognize the need to address China's dependence on low value-

[6] Carbon nanotubes (fullerenes) are derived from graphene, rolled into sheets and then tubes. They have a length to diameter ratio of up to 132,000,000 to 1, a magnitude much greater than conventional materials which endow them with unique strength, and properties such as thermal and electrical conductivity, making them ideal for incorporation into electronics and optics. See [5,21].

added export-led growth. As the Vice President of the China National Academy of Nanotechnology and Engineering (CNANE) notes, "China must break away from the mode of technology dependence and transform into independent technology innovation … It is very clear that [in China] the leading power is in the tight grasp of foreign enterprises" (as quoted in [5]).

China's science and technology policy is thus informed by a singular rationale: economic growth situated in the context of developing indigenous scientific and technological capacity to reduce reliance on technology transfer, export-led growth, and low end manufacturing. Importantly, China sees its science and technology policy as a central pillar in its efforts to become a global leader in innovation; a net exporter of ideas, innovative technologies and commercial applications.

3.1. State-led development of nanoscience and nanotechnology in China

China's science and technology programs are situated around a central policy architecture announced by Deng Xiaoping in 1986, the National High Technology Research and Development Program, known as the "863 program". The 863 program has been implemented through successive five year plans and is aimed at "promoting the development of key novel materials and advanced manufacturing technologies for raising industry competitiveness" including nanomaterials [5]. Between 1990 and 2002 the 863 Plan funded over 1000 nanotech projects with a total investment of USD 27 Million [8]. The program is managed by an expert responsibility system, with field-sector-specific expert committees and panels comprised of the nation's top scientists who supervise, advise and assess projects [2].

The first nano-specific project under the 863 program was the *Climbing Project on Nanomaterial Science* instigated between 1990 and 1999 and overseen by the State Science and Technology Commission (SSTC), the predecessor to the current Ministry of Science and Technology (MOST). Because of the Program's success the government subsequently renewed its commitment to funding basic research on nanomaterials and nanostructures (i.e. carbon nanotubes) with the initiation of *China's National Basic Research Program* (973 Program) in 1997. Since 2006, ten nanotechnology research projects have received a combined USD 30 Million (USD three million each) under the Program [1].

In addition to the 863 program, the 10th Five-Year Plan (2001–2005) also addressed priorities for the commercialization and development of nanotechnology. The government disaggregated nanotechnology development between short (development of nanomaterials), medium (development of bio-nanotechnology and nanomedical technology), and long-term projects (development of nano-electronics and nano-chips). The Five-Year Plan prioritized bridging the gap between nanotechnology research and market demand to form a complete national innovation system [2]. The 11th Five-Year Plan (2007–2012) in turn places emphasis on innovative technologies, including the development of new materials for information, biological and aerospace industries and industrializing the technology for 90-nm and smaller integrated circuits [75].

Under the medium and longer term master plan (MLP), nanotechnology development has been given priority status and is formally recognized as one of four "megaprojects" central to China's science and technological development and designed to reshape fundamentally China's R & D capacity [17]. To realize these ambitions, the government has set an ambitious target for national R&D spending of 2.5% of GDP (USD 4.3 Trillion) by 2020 (World Development Indicators; Medium to Long-term Plan for Development of Science and Technology), targeting R & D in nanomaterials and devices, nanoscale complementary metal-oxide semiconductor devices, nano-drug carriers, and nanomaterials (Medium to Long-term Plan for Development of Science and Technology). Between 2006 and 2008, the MLP funded 29 nanotechnology projects in 22 universities and research institutes across the country, totaling USD 38.2 million [6].

3.2. Chinese public perceptions of nanotechnology and nano-risks

While the full impact of China's push for leadership in nanotechnology and nanomaterials is yet to be realized, policy planning, regulation and management of the sector reveals much about Chinese public attitudes towards nanotechnology, and, in turn, how the discourse and management of possible nano-risks are framed and approached by public agencies and regulators. While nanotechnology holds enormous potential for commercial gain, cutting edge technological innovation and the development of an innovative knowledge economy, the risks associated with nanotechnologies and nanomaterials on human health and the environment remain largely unknown. Recent laboratory experiments on carbon nanotubes suggest that they could be as dangerous as asbestos fibres [3,28,58,66]. More importantly, nanotoxicity is thought to display an inverse relationship to particulate size; that is the smaller is the particulate matter the more toxic such particulates tend to be [54]. The precise dimensions of these risks, however, especially with longer term exposure or exposure through nanomaterials engineered in chemical composites and utilised in industrial and chemical applications are yet to be determined. For this reason, nanotech-specific safety regulations, toxicity and exposure levels have not been formalised or a commonly accepted international safety regulatory framework established [13].

In many countries science has historically approached new technologies by invoking the precautionary principle. Broadly stated, the precautionary principle assumes that if a technology or policy has a suspected risk of harm (to individuals, the public or the environment) absent scientific consensus about the extent and magnitude of these risks the burden of proof that the technology or policy is not harmful falls to its proponents. In China and the case of nanotechnology, however, the extent to which the precautionary principle guides the adoption of nanotechnologies and the use of nanomaterials is problematic. Several interrelated factors contribute to this.

First, the discourse framing China's pursuit of nanotechnology is tied intimately to a national political agenda.

As one of four science-based "megaprojects," nanotechnology occupies an iconic policy space that is highly politicised. Far from a science-based initiative, nanotechnology in China has thus to be appreciated in relation to centralised "command and control" economic planning and state-led development. Nanotechnology research and development thus operates under the burdens of expected national economic transformation, the delivery of substantial commercial outcomes, the development of a knowledge based economy, a reduction in China's technology dependence, and is one of the flagship programmes of China's ambition to assume global leadership in science and technology. Public perceptions of nanotechnology products and processes thus tend to be received and understood by public regulators in relation to sustaining and increasing national economic well being, the prospective assumption of global leadership in cutting edge technologies and science, and improving the quality of life for Chinese citizens; not as a health & safety risk prevention issue.

The framing of nanotechnology in such an overtly nationalist and aspirational contexts diminishes the political space for dissent or for the public to raise questions or concerns about safety issues, or risks associated with the impact of nanotechnology on human health and the environment. Rather, public perceptions of nanotechnology tend to be celebrated in concert with a "rising China" and as evidence of China's destiny to assume a global leadership role. The command and control style approach to national economic planning and the development of nanotechnology creates elite, technocratic processes, limiting the spaces for wider consultation or public participation about the role, desirability, potential applications, and impact of nanotechnology. In a sense, the public is shut out of the policy spaces around which science and technology policy is determined, or where risks and questions about potential harm from such technologies can be assessed. As the head of China's National Steering Committee for Nanoscience and Nanotechnology (NSCNN), the peak body overseeing nanotechnology in China observed, nanotechnology is highly technical, requires specialist knowledge, and since the public doesn't have the technical capacities or knowledge to understand the technologies or assess potential risks, its views can be largely ignored (interview, January 16 2010). Indeed, it was suggested that excluding the public or civil society groups from participation in reviews and debates was advantageous, since they might react inappropriately or form misperceptions about potential nano-risks due to technical deficiencies and a poor grounding in nanotechnologies. Involving the public or wider non-science-based communities in discussions was thus seen as possibly undermining national goals, not as a subject for public education as in many western countries (see also [57]).

This "knowledge deficit" problem, which in other national contexts sees the science community engage in outreach and education activities to raise evidenced based knowledge about new technologies, in China and the nanotechnology sector tends to lead to the provision of less information. This derives both from a hierarchical technocratic system where there is a collusion of interests between central planners and the nano-science community and because public perceptions toward science and scientists are deferential, with scientists highly respected and revered for their contributions to China's national economic advances. Such perceptions thus tend to reinforce the relative autonomy granted by the state to the nano-science community as the professionals most able to manage and assess the risks of nanotechnology (see also [15]). Such attitudes tend to moot vocal opposition, limit potential avenues for engagement between the science community and public/civil society groups, and lessen the incentives for scientists to disseminate evidenced based knowledge to the public.

These state-led and sanctioned political-social hierarchies tend to be self-reinforcing. Absent external, public based scrutiny, or the ability of civil society to engage critically with evidenced based risk assessments of nanotechnologies, concerns about the potential risks of nanotechnologies or exposure to nanomaterials are left to the science community to explore. The patron–client relationship that operates between central planners and the nano-science community, however, creates disincentives to design research programs focused on the risk impacts of nanotechnologies. Indeed, two senior Chinese nanoscientists when interviewed about possible conflicts of interest admitted that younger scientists are incentivised to under-report or downplay possible negative impacts of nanotechnologies. As they explained, funding streams for R & D are predominantly driven by the prospects for commercialization. Apart from establishing standards for nanotoxicity, researchers were incentivised to open nano-research avenues and not close them down through highlighting potential risks or downsides (interview, January 16 2010).

3.3. Conclusion

Public attitudes toward nanotechnology in China are firmly coloured and informed by their association with China's economic ambition to catapult itself into the forefront of global science and technology research and development. Few countries in the world have such a deeply entwined economic and political agenda meshed within a national science project [72]. China, in this sense, displays a situation where public attitudes towards nanotechnology are largely celebratory with nanotechnologies revered for their potential contributions to national economic transformation. The celebrated historical achievements of Chinese leadership in science and technology, and the deferential attitudes of the public towards science and scientists, lead to nanotechnologies being greeted not with any innate suspicion, but to be welcomed and perceived to be advantageous, bringing with them potential economic and social advancement.

In China there is, obviously, a deficit in public knowledge, participation and consultation concerning nanotechnologies. Aspects of state structure and behaviour such as command and control decision making, the patron–client relationship that exists between the state and nanoscience community, and the funding mechanisms that enable R & D into nanotechnologies, all contribute to discrete and relatively narrow spaces for public knowledge and engagement on nanotechnology issues. The result is a relatively positive or, at worst, benign set of public attitudes toward nanotechnologies.

4. Conclusion

The notion that new technologies are a growing area of policy concern is reflected in the increasing use of processes such as Danish-style consensus conferences in countries like Norway, the Netherlands, France, Japan, South Korea, New Zealand, the United Kingdom, and the United States [59]. The reception of controversial technologies like biotechnology in general [18,36,73], in the medical field [7,10,31], and of genetically modified foods in particular [26], has highlighted the need to better understand public opinion and attitude formation among consumers and observers of new products and processes. However the models which currently exist to explain public attitude formation towards controversial technologies are overly behavioural and societally-centric and fail to adequately address the ability of state actors in many countries to successfully articulate or direct public opinion.

A key under-explored factor in existing studies based on western democratic countries concerns the role played by governments in both creating and managing public opinion through publicity and public information campaigns framing technologies in positive ways—such as being linked to national survival or prosperity. Studies to date have focused mainly on developed liberal–democratic states which feature less active governments; however in many countries states play much more active and central roles in opinion formation both towards traditional subjects of state interest and towards novel innovative technologies.

As the two case studies presented here of active governments in Asia revealed, both in Singapore in the case of NEWater and in China in the case of nanotechnologies states played a much more significant role in opinion formation on controversial technologies than has hitherto been highlighted in the literature. Although with some very distinct differences given their different levels of democracy and the nature of their scientific and technology research and regulatory institutions, in both countries the state was able to frame a controversial technology as a key factor in national survival and/or national development. This framing was able to successfully overcome or avoid popular concerns with the technology and allow the state to pursue a much more promotional regulatory approach to the technology than would otherwise have been the case. Successfully convincing a large enough part of the public that little alternative exists to adopting a controversial technology thus appears to go a long way to overcoming cognitive, affective and attitudinal reservations to its generalization and use. This finding highlights the need for comparative studies of the subject to take the state more seriously in its research agenda and eschew generalizations based on biased case selection.

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